Demo: Low power, portable and infrastructure light indoor UWB ranging solution

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ABSTRACT

Indoor Positioning Systems (IPS) using ultra-wideband (UWB) are used in several application domains to optimize production processes and save expensive man hour costs. To deploy such a system, most solutions rely on an existing backbone network that is used for communication between the anchors and the Real Time Localization System (RTLS), which calculates the location. Our solution aims to be easy to install by using an IoT-standardized and low-power sub-GHz radio as backbone communication medium. Furthermore, using this low-power radio allows us to decrease the overall energy consumption of the anchors. In the demo we showcase that our solution does not require any wired connections and is a factor five more energy efficient than existing implementations.

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1 INTRODUCTION

Indoor positioning systems (IPS) aim to track objects, people or assets with the highest possible accuracy for a plethora of divergent use cases. Typically, anchors are placed at points with known coordinates, and the distance from an anchor to the moving tag can be estimated from Radio Frequency (RF) signals for the localization purpose.

One emerging RF technology for accurate localization is Ultra-Wideband (UWB) [1] ranging technology, which has excellent immunity against multipath fading and non-line-of-sight (NLOS) effects [2], and can achieve cm-level ranging accuracy [3].

One major drawback of using UWB is the high energy consumption. UWB consumes more energy in receiving mode than in transmitting, resulting in a high energy consumption in the typical always-RX systems where the transceiver is continuously listening for incoming UWB packets. Another problem arises with temporary installations where cabling and power infrastructure for the fixed UWB anchor nodes is not always present. Even permanent installations can require infrastructure free installations (protected buildings, huge warehouses, etc). The high cost of this infrastructure is limiting the adoption of large-scale UWB systems.

We propose to use a multi-radio system that can solve the need for infrastructure requirements for the anchors nodes. To leverage the benefits of multiple radios for an UWB localization system, we propose a novel MAC protocol. This MAC is designed to optimize the energy consumption of the battery-powered anchor nodes and to enable easy installation (plug and play) of these anchor nodes without requiring a wired infrastructure. This work includes a design of a scalable localization system that requires minimal pre-existing infrastructure by combining two wireless technologies: sub-GHz 802.15.4 for IoT-standardized long-range wireless communication backbone and UWB for localization. Moreover, the protocol optimizes the energy consumption of the UWB radio by designing a multi-technology, duty cycling time-slotted UWB MAC protocol.

2 SYSTEM DESCRIPTION

Our solution aims to minimize two shortcoming in currently available UWB solutions, namely (i) the need for a wired backbone and (ii) the large energy consumption of the anchor nodes. To remedy the need for wired access points, our solution connects UWB anchor nodes using a backbone of low-power sub-GHz communication which have a much larger range, of up to several kilometers [4]. To reduce the anchor node energy consumption, we observe that most UWB positioning systems use always-on UWB radios, which are highly energy consuming. Since the mobile UWB tag will not be present continuously at each location, we propose to turn off the UWB radio when no tag is nearby. Instead, UWB anchor nodes continuously listen using their low power sub-GHz radio. The tag will activate anchor nodes using a low-energy sub-GHz activation beacon when nearby, but only (i) when the tag actually wants to range with the anchor node and (ii) during a small time slot. As such, anchor nodes remain in a low-power mode most of the time, and only activate the UWB radio during short timeslots when tags are nearby.

Hardware. Since no current UWB hardware boards support sub-GHZ technologies, an existing sub-GHz IoT platform is used: the Zolertia RE-Mote [5]. The Zolertia RE-Mote supports two low-power IoT radios (CC1200 and CC2538), from which only the CC1200 sub-GHz radio was used in this paper. A custom UWB add-on board was designed that can be easily mounted as a shield on the Zolertia

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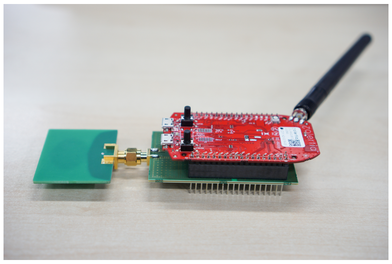

Figure 1: Zolertia RE-Mote equipped with custom shield containing Decawave DW1000 UWB radiochip and flexible antenna interface.

RE-Mote. The shield is designed around the Decawave DW1000 [6] UWB transceiver. To improve the positioning performance, the UWB hardware board supports a flexible antenna interface (SMA connector), allowing the use of external dedicated antennas, designed and optimized for specific use cases.

Software. The Zolertia RE-Mote supports the Contiki OS, which includes a full IoT protocol stack for wireless mesh backbones using open IPv6 supported standards such as RPL and 6LowPAN. To implement the MAC layer, a custom implementation was required. To this end, the multi-technology MAC protocol was implemented using the Time Annotated Instruction Set Computer (TAISC) framework [7], which supports the design of TDMA MAC protocols that use multiple radios.

MAC Protocol. The MAC protocol uses a Time-Division Multiple Access (TDMA) channel access approach, which partitions time in repeating superframes. A superframe is a sequence of slots, where each slot corresponds to a specific action to take (e.g., receiving or transmitting a UWB message). This requires all participating devices to be synchronized in time. Since UWB radios consume more energy than common narrowband IoT transceivers, a separate transceiver is used for all synchronization and reporting communication. The UWB radio is only used to range between the mobile tag and the different anchors. Time synchronization is initiated by the tag during the first slot of the superframe where the mobile tag broadcasts a sub-GHz beacon packet to all nearby anchor nodes ('Beacon' slot in Figure 2). The beacon contains a list of anchors with which the mobile tag wants to range, as well as their assigned ranging TDMA slot. All anchor nodes receiving the beacon know if and when they have to activate their UWB radio. In case the anchor node address is not included in the list, the anchor node can go to sleep mode until the next superframe. Next, a single UWB polling message is first broadcasted ('Poll' slot in Figure 2) to all nearby anchor nodes that turned on their UWB radio. Afterwards, UWB slots are provided for sequentially calculating the distance to all selected anchor nodes ('Ranging slot' in Figure 2). After each ranging slot, a reporting slot is provided to send the calculated distance to a back-end system. The complete structure of the superframe is illustrated in Figure 2.

Performance. When implementing the multi-technology MAC protocol, the anchor requires on average 26 mA in a superframe where it was selected by the tag, and 3.5 mA when the anchor is in standby mode (not selected for ranging). This is a factor of five times more energy efficient than existing ("always-RX") implementions which requires on average 130 mA. The protocol can be improved by several optimizations to achieve ranging update rates of up to 372 Hz experimentally and even up to 2892 Hz theoretically when no hardware dependent delays are taken into account.
The full technical details and performance analysis of the protocol can be found in [8].

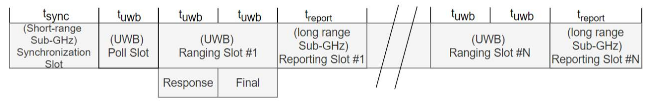

Figure 2: MAC superframe structure with different slots for synchronization, ranging and reporting.

3 DEMONSTRATION AND INTERACTION

In our demonstration we prove and show the difference in energy consumption on the anchors between our MAC solution and a typical ("Always RX") implementation. In the setup, three anchors and one mobile tag will be used. Two anchors are using our solution, while the third anchor uses a always RX implementation. The always-RX implementation simply turns on the UWB radio on startup and waits for a incoming poll message. Each anchor will be connected to a power analyser showcasing the improvement on energy consumption using our proposed solution compared to a typical always-RX solution. People can walk around with the mobile tag and see their position visualized on a map.

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